Vital and Health Statistics

April 2014

Series 2, Number 164

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Data Evaluation and Methods Research

National Center for Health Statistics

Charles J. Rothwell, M.S., M.B.A., *Director*

Jennifer H. Madans, Ph.D., *Associate Director for Science*

Division of Health Interview Statistics

Jane F. Gentleman, Ph.D., *Director*

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Acknowledgments

Comparison of In-home Collection of Physical Measurements and Biospecimens With Collection in a Standardized Setting: The Health Measures at Home Study

by Renee M. Gindi, Ph.D., Division of Health Interview Statistics; George Zipf, M.S., Division of Health and Nutrition Examination Surveys; Adena M. Galinsky, Ph.D., Division of Health Interview Statistics; and Ivey M. Miller, R.T.R., Tatiana Nwankwo, M.S., and Ana L. Terry, M.S., R.D., Division of Health and Nutrition Examination Surveys

Abstract

Objectives

Collection of physical measurements and biospecimens in the home may be an efficient way to obtain objective health measurements. This study assesses differences between collection in the home and a standardized setting.

Methods

Participants had physical measurements and biospecimens taken in the National Health and Nutrition Examination Survey mobile examination center (MEC). Then, they had height and weight measured in the MEC using portable equipment. In the home, participants had height, weight, and blood pressure measured and dried blood spots collected using portable equipment. Two complete examinations were done in the home: one by a health technician and one by a field interviewer.

Results

Home environments were less standardized and presented more challenges to examiners. Correlations between all four height measurements and all four weight measurements were higher than 99%. Mean differences in height (0.3 cm) and weight (0.4 kg) were small but statistically significant. The home measurements perfectly or near-perfectly classified participants as obese relative to the standardized MEC examination.

Conclusions

The selected physical measurements can be collected in the home by field interviewers using portable equipment. Before adding home collection of physical measurements to household interview surveys, further research should be done to examine the impact of these changes on interviewer training, participant recruitment, and participant response rates.

Keywords: National Health Interview Survey • National Health and Nutrition Examination Survey • biomarkers

Introduction

The Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS) conducts two nationally representative surveys that are principal sources of information on the health of the U.S. population: the National Health Interview Survey (NHIS) and the National Health and Nutrition Examination Survey (NHANES). NHIS conducts about 35,000 face-to-face household interviews per year and collects information on a broad range of health topics, including health care access and utilization and health conditions. NHANES interviews and examines a sample of approximately 5,000 individuals per year. The examination component consists of medical, dental, and physiological measurements as well as laboratory tests.

Together, the two surveys provide complementary information about the health of the U.S. population. Because of the large sample size, NHIS produces reliable annual estimates of health characteristics among demographic subgroups (e.g., race and ethnicity, age, and disability status) (1), and geographic subgroups (e.g., state-based estimates) (2), as well as quarterly estimates on selected characteristics of the health of adults (3). However, estimates based on self-reported health data may severely underestimate the true prevalence of health conditions in the United States due to reporting bias (4,5), recall bias (6,7), or a lack of awareness of the condition (8–10). Adding confirmatory physical measurements to the existing NHIS household interview could provide objective measurements of some health conditions as well as a mechanism for the measurement and control of these biases.

Recent technological advances allow nonmedically trained persons, such as field interviewers, to conduct physical examinations and collect biospecimens (11–14). For example, automatic oscillometric blood pressure machines have been demonstrated to obtain blood pressure readings with a high degree of accuracy (15), and are

frequently used by people without medical training (e.g., home blood pressure monitoring) (16,17). Dried blood spots (DBS) allow for the collection of a biospecimen without employing phlebotomists, instead using a finger stick (18). DBS are stable and can be sent through the mail without the techniques necessary for storing and transporting whole blood (19).

However, comparisons of physical examinations conducted and biospecimens taken in the home from the National Longitudinal Study of Adolescent Health and the New York City Health and Nutrition Examination Survey I with those obtained by NHANES in the mobile examination center (MEC) for similar populations suggest differences may exist between the two data collection strategies (20,21). While one study compared the operational impact of having interviewers rather than nurses collect biomarkers in the home (22), to the authors' knowledge, no published studies have systematically compared physical measurement data collected in the home to data collected on the same respondent in a standardized setting like the NHANES MEC.

The Health Measures at Home Study (HMHS) was conducted to determine whether physical examinations could be conducted and biospecimens collected in the home by nonmedically trained interviewers and produce data comparable to those produced in a standardized research setting. This report addresses three potential sources of variability between in-home examinations and NHANES standardized examinations: the use of portable equipment (compared with standard MEC equipment), a nonstandardized environment (compared with the standardized MEC environment), and field interviewers conducting the examinations (compared with health technicians).

Methods

Study Population

HMHS participants were a convenience sample of NHANES participants aged 18 and over. NHANES is a cross-sectional national health survey of the civilian noninstitutionalized U.S. population. Descriptions of the NHANES sample design and data collection methods are available on the NHANES website at www.cdc.gov/nhanes. The NHANES MEC travels to 15 locations each year (23), and participants in these locations are randomly selected. Participants are interviewed in their homes and then examined in the MEC.

NHANES participants aged 18 and over who had completed the blood draw as well as height, weight, arm circumference, and blood pressure measurements at the NHANES MEC were eligible to participate in HMHS. Participants were recruited at the end of their NHANES examinations. They were excluded from HMHS if they required a proxy to respond for them, were unable to complete the study in English, were pregnant, or had a physical condition that precluded the collection of accurate physical measurements and biospecimens. At the conclusion of HMHS, participants received $60. The NCHS Research Ethics Review Board approved all HMHS examination components and the study protocol.

Study Design

This study addresses three potential sources of variability between measurements taken in a standardized research setting and measurements taken in the home, comparing: 1) standardized MEC equipment and protocol to portable equipment and protocol; 2) standardized to nonstandardized environments; and 3) health technicians (with more health sciences training and experience) to field interviewers (with no health sciences training and experience). The study design is summarized in Figure 1.

HMHS uses a repeated measures design, with four sets of measurements for each participant. The first set is obtained as part of the standard NHANES examination. Participants' height, weight, and arm circumference were measured by a health technician, and blood pressure was obtained by a physician (Figure 1, Measurement set 1). A certified phlebotomist drew 115 mL of blood to test for various blood analytes, including hemoglobin A1c (HbA1c), total cholesterol, and high density lipoprotein (HDL). This part of the examination was conducted using standard NHANES equipment and protocols (24–26) in the standardized research setting of the MEC. The order of measurements could vary, but all were completed prior to HMHS recruitment.

Using a standard script, MEC staff members recruited eligible NHANES participants for HMHS. Once recruited for HMHS, the participant had a second set of height and weight measurements taken at the MEC by a health technician (Figure 1, Measurement set 2). Although these measurements were taken in the MEC, the health technician used the portable equipment and protocols that were designed for use in the home. Height was measured first, using a portable stadiometer. Weight was measured next, using two different portable scales. The order in which the scales were used was randomized (Figure 1, R2). Due to operational constraints, it was not possible to measure blood pressure a second time or to collect DBS in the NHANES MEC, resulting in a reduced second set of measurements for all participants.

The third and fourth sets of measurements were taken at the participant's home approximately 1 to 3 weeks after the NHANES MEC examination (Figure 1, Measurement sets 3 and 4). Home examinations were scheduled as close as possible to the same time of day as the MEC examination, with some flexibility to encourage participation. The order of the home examination was as follows: DBS, height, weight, and blood pressure. The entire third set of measurements was

	Measurement set 1	Measurement set 2	Measurement sets 3 and 4
Environment	NHANES MEC	NHANES MEC	HMHS participant's home
Time	NHANES examination	After NHANES examination (same visit)	1–3 weeks after NHANES examination
Examinations	NHANES: Height, weight, arm circumference, blood pressure, phlebotomy	HMHS: Height, weight (two scales)	Dried blood spots, height, weight (two scales), blood pressure
Examiners	Health technicians, physicians, phlebotomists	Health technicians	R1 ⎰ 1. Health technician / 2. Field interviewer ⎱ 1. Field interviewer / 2. Health technician
Equipment	Standard NHANES MEC equipment	Portable equipment R2 ⎰ 1. Stadiometer / 2. Tanita scale / 3. Seca scale ⎱ 1. Stadiometer / 2. Seca scale / 3. Tanita scale	Lancets and filter paper for dried blood spots; portable stadiometer, Seca scale, Tanita scale, (randomized order as in R2); automated blood pressure measurement device

R1 is randomized order of examiners.
R2 is randomized order of weight scales (same order for measurement sets 3 and 4 as well).

NOTES: NHANES is National Health and Nutrition Examination Survey. MEC is mobile examination center. HMHS is Health Measures at Home Study.

Figure 1. Study design for the Health Measures at Home Study, 2012

completed by one examiner before the fourth set of measurements was taken by the other examiner.

The order of the examiners was randomized so that for one-half of participants, the third set of measurements was collected by the health technician and the fourth set by the field interviewer (Figure 1, R1). For the other one-half of participants, the third set was collected by the field interviewer and the fourth by the health technician. This was done primarily to address order effects in blood pressure measurement (27). To minimize the possibility that field interviewers, who had less health sciences training and experience, would model their examinations after the health technicians' [i.e., analogous to contamination bias (28)], examiners were not permitted to watch each other conduct the examination. In practice, this meant that while one examiner performed examinations, the other

examiner was outside, in another room, or in the same room but facing away while wearing headphones.

Portable equipment was used in the home, including a portable stadiometer, two portable scales, an automatic blood pressure machine, and DBS cards and lancets. The scales were used in the home in the same order as the second set of measurements at the NHANES MEC (Figure 1, R2). While the field interviewers were responsible for setting up all of the equipment in the home, the health technicians were able to reposition the equipment when they felt that it was necessary.

Variability between standard MEC equipment and portable equipment for height and weight measurement is addressed by comparing Measurement set 1 with Measurement set 2, keeping environment and examiner type constant. Variability between portable scales is examined, keeping examiner type and environment constant.

Variability between the standardized and home environments is addressed by comparing Measurement set 2 with Measurement sets 3 and 4 (health technicians only), keeping equipment and examiner type constant. Variability in the examiner type is examined, keeping the environment and the equipment constant.

Consent and Reporting

NHANES MEC staff who recruited the participants obtained informed consent. Participants signed an electronic consent form and received an unsigned paper copy. At the conclusion of the MEC examination, participants were given a preliminary Report of Findings, which included blood pressure, height, weight, and a complete blood count. NHANES participants received a mailed report of findings 3 to 4 months after their examination, which included results of more detailed clinical

Table A. Standard National Health and Nutrition Examination Survey mobile examination center equipment and portable equipment used for the Health Measures at Home Study

NHANES MEC equipment	Portable equipment
Height	
Fixed stadiometer	Seca 214 portable stadiometer
Weight	
Digital weight scale	Seca 876 portable digital weight scale
Portable scale (backup)	Tanita HD-351 portable digital weight scale
Blood pressure	
Mercury sphygmomanometer with stethoscope	Omron HEM-907XL
Baumanometer cuffs	Omron cuffs
Cuff sizes: small (17–21.9 cm); adult (22–29.9 cm); large adult (30–37.9 cm); and extra-large adult (38–47.9 cm)	Cuff sizes: small (17–21.9 cm); adult (22–31.9 cm); large adult (32–41.9 cm); and extra-large adult (42–50 cm)
Arm circumference directly measured	Arm circumference estimated with regression equation
Blood analytes	
Nipro 19-gauge; Becton Dickinson Vacutainer Safety-Lok 21- and 23-gauge blood collection sets; Vacutainer containers	Two Becton Dickinson microtainer contact-activated lancets; Ahlstrom 226 filter paper

NOTES: NHANES is National Health and Nutrition Examination Survey. MEC is mobile examination center.

measurements. At the conclusion of the home examination, participants were given a blood pressure report. A mailed report of findings was not provided for the HMHS home examination.

Equipment

Table A highlights differences between the NHANES MEC equipment and the portable equipment. Portable equipment was selected for durability, weight, and ease of transport as well as data collection accuracy. All equipment, exclusive of the interviewer laptop computer, could be transported in a single hard-shelled suitcase with wheels. The suitcase dimensions were 32.6'' x 23.4'' x 13.7''. Fully loaded with equipment, the suitcase weighed 38 lbs. The Fujitsu T2020 laptop computer, peripherals, and bag weighed an additional 10 lbs. 9 oz. The contents of the suitcase are listed in Table B.

The following sections describe each measurement component in more detail. The standard MEC protocol is noted briefly before providing a more detailed description of the portable equipment, the data collection protocol, and the calibration protocol.

Height

The height measurement during the NHANES MEC portion of the study was obtained following standard NHANES protocols (24). Briefly, a health technician took a height measurement in centimeters (cm) using a fixed metal stadiometer that was connected to a computer. The examiner asked the participant to remove shoes as well as any hair ornaments, jewelry, buns, or braids. (If the participant refused to remove an item, the examiner measured the item with a ruler, and the value was used as a height correction factor.) The examiner then slid the headpiece of the stadiometer to the top of the measurement column. The participant was instructed to stand erect on the platform with the back aligned with the vertical column of the stadiometer, the body weight evenly distributed, and both feet flat on the platform. The participant stood with heels together, feet pointed slightly outward at a 60° angle, with both arms hanging freely and palms facing the thighs. The examiner positioned the participant's head in the Frankfort horizontal plane, with the horizontal line from the ear canal to the lower border of the orbit of the eye parallel to the floor and perpendicular to the vertical column. The examiner slid the plastic headpiece down onto the participant's head and told the participant to take a deep breath. A deep breath allowed the spine to straighten, yielding a more consistent and reproducible height

measurement. When the participant was properly positioned, the health technician told the recorder (a staff member assisting the technician) to press a button on the computer that automatically captured the height. The captured result was repeated out loud and verified by the health technician. Any height correction values were entered manually into the computer, which automatically calculated an adjusted height value.

The Seca 214 collapsible stadiometer was the portable equipment used in HMHS. Measurements were taken and recorded in cm. Measurement protocols were exactly the same as those in the NHANES MEC, with the exception of measurement capture. For these measurements, the examiner read the value on the portable stadiometer and manually entered it into the computer. The start and stop times of this component of the examination were collected automatically by the computer based on movement through the survey instrument. Component duration (in minutes) was saved to the participant's record.

The fixed stadiometer used at the MEC was calibrated at the start of data collection in each MEC location and weekly thereafter with an 80-cm metal rod consistent with the standard NHANES MEC calibration protocol. The portable stadiometers were calibrated with the same procedures but on a different schedule. The portable stadiometer at the MEC was calibrated weekly. The portable stadiometers used in participants' homes were calibrated at the start of data collection in each location and monthly thereafter.

Weight

The weight measurement during the NHANES MEC portion of the study was obtained using a fixed scale following standard NHANES protocols (24). Briefly, participants were weighed in kilograms (kg) using a fixed digital weight scale. Participants at the MEC wore standard paper examination gowns (shirt, pants, and slippers). After the participants were correctly positioned (in the center of the scale platform facing the health technician, hands at sides, and

Table B. Contents of suitcase with sufficient supplies for two visits: Health Measures at Home Study, 2012

Activity	Item name	Quantity
Computer	Contact folder	1 or more
General	Checks	4
Computer	Tablet computer and accessories	1
General	Extension cord	1
General	Purell wipes	1
General	Hand sanitizer	1
General	Pen or marker	2
General	Stop watch	1
DBS	Holding box for DBS card[†]	2
DBS	Sterile lancet[†]	10
DBS	Alcohol wipe[†]	2
DBS	Sterile gauze pad[†]	2
DBS	Filter paper or DBS card[†]	2
DBS	Adhesive bandage[†]	2
DBS	Shipping bag[†]	2
DBS	Ziploc with supplies	2
DBS	Alcohol wipes, extra	10
DBS	Sterile gauze pads, extra	10
DBS	Adhesive bandages, extra	10
DBS	Desiccant packs	10
DBS	Biohazard bags	4
DBS	50 mL conical tubes (in-home lancet disposal)	4
DBS	Warming packs	4
DBS	Disposable lab coats, medium	4
DBS	Disposable absorbent pad (blue chux)	4
DBS	Sterile, nonlatex gloves, medium	12
DBS	Sterile, nonlatex gloves, small	12
Anthro	Seca scale	1
Anthro	Tanita scale	1
Anthro	Stadiometer	1
Anthro	Height adjustment ruler	1
Anthro	Step stool	1
Anthro	AA batteries for scales	10
Anthro	Extra AA batteries for scales	6
BP	Omron machine	1
BP	Cuffs (small, adult, large adult, and extra-large adult)	1 set
BP	Cuff air tubing	1
BP	AC adapter for Omron machine	1
BP	Foam pads to support arm	1
BP	Foam pads to support proper positioning of feet	1
DBS	Laminated sheet (protocol)	1
Anthro	Laminated sheet (protocol)	1
BP	Laminated sheet (protocol)	1

[†] Part of a prepackaged kit from ZRT Laboratories. Five kits were included in each suitcase. Quantities reflect the number of items in each kit.

NOTES: DBS is dried blood spots. Anthro is anthropometry. BP is blood pressure.

looking straight ahead), the weight was automatically captured by a computer attached to the scale.

Portable equipment used in the MEC and in the home included the Seca scale model 876 (Seca scale) and the Tanita HD-351 scale (Tanita scale). The Seca scale is a slip-proof, portable, professional digital weight scale, which has a maximum capacity of 550 lbs (250 kg). The Tanita scale is a portable digital weight scale designed for personal use, which has a maximum capacity of 440 lbs (200 kg). The order in which the two scales were used was randomized at the start of the study, and this order was retained for the second, third, and fourth sets of measurements. The protocols used for both the fixed and portable scales at the MEC were the same, with the exception of measurement capture. When using the portable scales, the examiner manually entered the value into the computer.

In the home, participants wore their own clothing, but the examiner asked the participant to remove their shoes and to remove any items from their pockets. After the participants were correctly positioned (in the center of the scale platform facing the health technician, hands at sides, and looking straight ahead), the examiner manually entered the weight value into the computer. The duration of this component of the examination was collected automatically by the computer.

The Seca scales were calibrated with eleven 10-kg weights, consistent with the standard NHANES MEC calibration protocol. The Seca scales used at the MEC and those used in the participants' homes were calibrated monthly. The Tanita scale self-calibrated each time it was turned on and did not require weights for calibration.

Blood pressure

Blood pressure measurements performed in the NHANES MEC used auscultation and followed the standard NHANES protocol (25). Midarm circumference was measured in cm during the MEC anthropometry examination (24). Prior to the start of blood pressure measurements in the MEC, the blood pressure cuff was selected based on the midarm circumference measurement. Four cuff sizes were available: small, adult, large, and extra-large. Blood pressure was measured on the right arm unless specific conditions precluded the use of the right arm. If measurements could not be taken on the right arm, the left arm was used. The blood pressure cuff was placed correctly on a bare arm by the physician, and the participant was seated with back supported, feet resting flat on the floor, and forearm on a level surface at heart level. The participant was then instructed not to speak or move for 5 minutes. After the waiting period, three systolic and diastolic measurements were obtained at 30-second intervals by a physician using a wall-mounted mercury sphygmomanometer. Each successive measurement was manually entered by the physician in a computer.

Blood pressure measurements performed in the home used oscillometric methods and followed procedures that mirrored those on the MEC as closely as possible. The Omron IntelliSense Blood Pressure unit, Model HEM-907XL (Omron), measured blood pressure using compression of the

brachial artery under an elastic, inflatable cuff and estimation of the systolic and diastolic blood pressure levels. This automatic device was chosen because it satisfied both the Association for the Advancement of Medical Instrumentation and the British Hypertension Society criteria for blood pressure devices (29,30) and had been validated in a prior NHANES methodology study (15). The monitor included blood pressure cuffs with built-in inflatable air bladders and an air tube that connected to the Omron unit. Four cuff sizes were available: small, adult, large adult, and extra-large adult. The cuff size was selected based on a regression equation to estimate arm circumference (31). The participant's sex, age, height measured at home, and weight measured using the Tanita scale at home were used as inputs into the regression equation. This calculation was done automatically and the appropriate cuff size displayed on the computer screen. Blood pressure was measured on the right arm unless specific conditions precluded the use of the right arm. If measurements could not be taken on the right arm, the left arm was used.

A quiet location was selected for the blood pressure readings. The examiner asked the participant to sit in a chair with his or her back supported and feet resting flat on the floor. The examiner placed the Omron on a solid surface, such as a table near a power outlet. If an outlet was not available, the Omron operated with a portable battery. In homes with suboptimal environments (e.g., noise, distractions, no chair), the examiner was expected to adhere as closely as possible to the protocol. If the participant was wearing clothing with sleeves, regardless of length, he or she was asked to roll up the sleeve. If the participant was unable or refused to roll up the sleeve, the blood pressure measurements were taken over the sleeve.

After the blood pressure cuff was placed correctly and the participant was positioned properly, the participant waited 5 minutes, during which time he or she was instructed not to speak or move. The examiner set the device to take three consecutive blood pressure

measurements with 30-second intervals between inflations. Each measurement was manually entered into the computer twice to reduce data entry errors.

Due to concern that some participants would not want to roll up their sleeves for blood pressure measurements (32), blood pressure measurements over clothing were tested as part of the protocol development for blood pressure collection in the home. For those participants who were wearing clothing with sleeves and had previously agreed to roll up their sleeves, an additional set of blood pressure measurements was taken over the sleeve by the field interviewer but not by the health technician. In these cases, the cuff was placed over the right sleeve, and after a 1-minute waiting period, the device took three consecutive blood pressure measurements with 30-second intervals between inflations. Each measurement was manually entered into the computer by the field interviewer twice to reduce data entry errors.

While the duration of the complete blood pressure measurement component was collected automatically by the computer, it did not allow for a separate duration to be collected for each of the consecutive blood pressure measurements. In cases where the participant was wearing clothing with sleeves, the field interviewer's complete blood pressure component duration includes the time needed for a second set of measurements over the sleeve, while the health technician's blood pressure component duration does not.

Field interviewers maintained and calibrated the blood pressure equipment. Each day, field interviewers inspected and cleaned the Omron unit. Each month, they calibrated the Omron units using a Netech Digimano 2000 pressure vacuum gauge. Comparison values between two properly functioning devices were expected to fall within +/- 3 mmHg.

Venous blood draw and DBS

Phlebotomy was performed during the NHANES MEC portion of the study following the standard NHANES protocol (26). Briefly, a certified phlebotomist obtained a venous blood

sample from participants in the MEC phlebotomy room. Phlebotomy was done as soon as scheduling permitted in a participant's MEC visit, and some participants were asked to fast before their appointments. Participants were asked to make (but not pump) a fist to prepare for a venipuncture of the left arm (preferred). The appropriate needle size was selected depending on the condition and size of the participant's veins. Blood was drawn while participants were seated or in a supine position, never while participants were standing. Two venipuncture attempts were allowed per participant to obtain 115 mL of blood.

A participant was excluded from venous blood collection for the following reasons: hemophilia; chemotherapy within the last 4 weeks; presence of rashes, gauze dressings, casts, edema, paralysis, tubes, open sores, or wounds; withered arms or limbs missing; damaged, sclerosed, or occluded veins; allergies to cleansing reagents; burned or scarred tissue; or shunt or intravenous lines on both arms.

DBS were obtained in the participants' homes following protocols developed specifically for home DBS collection. A DBS collection kit included two Becton Dickinson microtainer contact-activated lancets, Ahlstrom 226 filter paper (DBS card), alcohol wipes, gauze pads, bandages, nonlatex gloves, a biohazard bag, hand sanitizer, and unique identification labels. Hand-warming packs were also available. A plastic storage box, desiccants, and a shipping bag were used for storing and shipping the DBS cards.

As a precaution, the participant was asked to sit during the DBS collection to avoid falling if he or she became faint or queasy. The examiner was instructed to ask the participant to rub his or her hands together, to hang both hands by his or her sides, and to pump both fists to increase blood flow to the fingers. Examiners could offer hand-warming packs to participants with cold hands.

DBS were collected by pricking the participant's ring or middle finger with a disposable lancet with a permanently retractable blade. No more than two

fingers were pricked, with a separate lancet used for each. The first drop of blood was wiped away with gauze, and the five subsequent drops were spotted on the DBS card. The examiner followed universal safety precautions to minimize risk of infection from bloodborne pathogens. The examiner manually entered in the computer the number of fingers pricked and the number of blood spots obtained. The start and stop times of this component of the examination were collected automatically by the computer based on movement through the survey instrument. Component duration (in minutes) was saved to the participant's record.

The same exclusion criteria applied to both venous blood collection and DBS collection.

Blood specimen handling and shipping

In the MEC, Vacutainer tubes are labeled with the unique participant ID number before venous blood is drawn. Venous blood is first processed on the same day that it is collected in the MEC laboratory. Complete blood counts are obtained, and blood is allocated into 48 vessels for storage and transport to 24 laboratories across the United States for analysis. Vessels with venous blood samples to be tested for HbA1c are refrigerated and shipped weekly to the NHANES Diabetes Laboratory; those to be tested for total cholesterol and HDL are frozen and shipped weekly to the NHANES Diabetes Laboratory.

In the home, DBS cards were labeled with two bar code labels: one with a unique participant identification number and another with a unique laboratory specimen number. Labels were placed on the DBS cards while still in the participant's home. The participant's name was not included on the DBS card. The DBS card was placed in a protective plastic container with the lid open, allowing it to dry for 30 minutes while the examiner measured height, weight, and blood pressure. The plastic container and the desiccant were then placed in a shipping bag at the end of the examination and allowed to dry overnight at the

Table C. Standard mobile examination center environment and nonstandard home environment

MEC	Home
Atmosphere	
Temperature-controlled	Not necessarily temperature-controlled
Quiet, with some soundproofing	Potentially noisy
Private	Space may be shared with others
No interruptions to data collection	Data collection subject to interruption
Equipment	
Stationary, set up once per MEC location	Portable, set up at each home visit
Furniture, flooring, and specimen storage	
Furniture designed to protocol	Furniture may not be appropriate
Leveled and tiled floors	Floors may be carpeted or uneven
Freezers, centrifuges, and laboratory	Storage of biospecimens must be portable
Hood for biospecimens	No hood for biospecimens
Participants	
Wearing MEC-issued disposable gowns	Wearing own clothing

NOTE: MEC is mobile examination center.

NHANES field office. DBS cards were processed and stored at ambient temperatures. Samples were shipped on the business day following collection via Federal Express Priority Overnight.

Specimen laboratory methods and quality control

Venous blood was shipped from the MEC to the NHANES Diabetes Laboratory to test for HbA1c, total cholesterol, and HDL as part of the standard NHANES biospecimen analysis. The laboratory methods for detection of these analytes are standardized and validated.

DBS samples obtained in the home were shipped to ZRT Laboratory in Beaverton, Oregon, to test for HbA1c, total cholesterol, and HDL. The laboratory methods for detection of total cholesterol and HDL have not yet been standardized and validated. In some cases, not enough blood was obtained to test for all three analytes. These samples were described as quantity not sufficient (QNS). This study prioritized analysis of total cholesterol and HDL over HbA1c in QNS samples. ZRT is a CLIA-accredited analytical laboratory. Quality control testing included results from 2% of random repeat samples to monitor test result reproducibility, and comment codes were recorded when quality control results were beyond acceptable ranges. ZRT maintained a log that

recorded the status of all blood spots upon arrival, with details regarding deviations from the standard operating procedure or good laboratory practice (e.g., improper labeling or packaging, or no desiccants) that could affect the quantitative results.

Environment

HMHS provides an opportunity to compare the standardized MEC environment and nonstandardized home environments (Table C). The MEC is designed to be private and to minimize distractions or disruptions (23). MEC trailers are temperature-controlled and leveled, and the floors are tiled. Custom furniture, such as chairs with adjustable arms, facilitate measurement of blood pressure and collection of venous blood. Participants wear MEC-issued examination gowns, which help to keep weight measurements standardized.

In contrast, examinations conducted in the home are subject to a variability that may affect some or all of the measurements. The home environment may not be private and is subject to distractions and noise, which may influence blood pressure measurements. The area may not have temperature controls, which may affect DBS collection. Floors may not be completely level and may have carpet or other coverings, which could impact height and weight measurements.

Table D. National Health and Nutrition Examination Survey health technicians and field interviewers, by education and experience

Characteristic	Health technician	Field interviewer
Minimum education	Associate's degree in health science; bachelor of science preferred	High school diploma
Minimum certification	CPR	None
Minimum years of experience in health sciences	1 year or more	None

NOTE: CPR is cardiopulmonary resuscitation.

Furniture in the home may not be appropriate for collection of any or all of the physical measurements or biospecimens. In the home, participants wear their own clothing, which may have an impact on the measurements of blood pressure, height, and weight.

Examiner Skills and Training

HMHS provides an opportunity to compare the measurement skills of health technicians, who have more health sciences experience, with those of field interviewers, who have little to no health sciences experience (Table D). At a minimum, NHANES health technicians have an associate's degree in health science or higher, with a bachelor of science degree preferred. They are certified in cardiopulmonary resuscitation (CPR) and have 1 year or more of health sciences experience. Health technicians receive extensive training on performing examinations and collecting biospecimens. During data collection, their performance is monitored on a regular basis to ensure data quality. Each year, they receive instruction in a centralized location regarding changes to any laboratory or component protocol or procedure that will be implemented in the coming year. By contrast, at a minimum, NHANES field interviewers have a high school diploma and do not need to have any certifications or health sciences experience. Field interviewers do not collect physical measures or biospecimens in the NHANES MEC.

Six field interviewers and two health technicians were selected and trained specifically on HMHS data collection protocols. HMHS training occurred immediately prior to the study in a centralized location. Information on

the study objectives, the reason and protocol for each measurement, and completion of the examiner feedback were presented in didactic format. Over the course of 5 days, training totaled 28 hours, with a heavy focus on practicing each measurement. One of the health technicians was already familiar with some of the portable equipment protocols and attended only a 1-day refresher training.

Supervisors and trainers were on call during work hours to respond to questions about data collection. While two "lessons learned" debriefings were held, formal retraining on all components was not offered during the course of the study.

Additional Data Sources: Examiner Feedback

To provide insight into the range of conditions under which it is possible to obtain measurements in the home, examiners completed the Home Exam Debriefing Questionnaire at the conclusion of each home examination (Appendix). This questionnaire addressed challenges encountered in the field, protocol adjustments used to overcome these challenges, equipment performance, home environment, and participant behaviors and characteristics. The questionnaire provided an additional source of information (beyond physical measurement values) about potential sources of variability covered by this report: examiner skill level, environment, and equipment. A subset of the data collected is considered in the current report.

Information about variability between standard MEC equipment and portable equipment was collected using two types of questions—questions about problems that the examiners encountered

while using the equipment (specifically, DBS and blood pressure), and questions about why examiners may have been unable to obtain height, weight, or blood pressure measurements. Examiners were also asked about difficulty with transferring the equipment in and out of the participant's home.

Data about home conditions that may explain variability between measurements taken in standardized and home environments were collected using questions on disruptions during the examination, room temperature, and availability of appropriate furniture or flooring to set up equipment. In addition to a set of questions on noise and disruptions during the entire examination, additional questions were asked about disruptions during the blood pressure measurement due to the particular sensitivity of such measurements to disruptions. Examiners were asked to rate the room temperature as hot, warm, cool, or cold; it was not objectively measured. The absence of an appropriate table or chair was ascertained via six questions: one which asked if the examiner used other furniture or objects during the DBS collection because no standard table or chair was available; one which asked if no chair with a back was available so that the participant had to sit on some other surface for the blood pressure measurement; two open-ended questions which asked about other problems encountered during DBS collection or blood pressure measurement; one follow-up open-ended question which asked if the examination quality was less than excellent and if so, why; and one which asked if the Omron machine was placed on the floor because no higher surface was available. The absence of appropriate flooring for anthropometry was ascertained with questions about characterizing the flooring as either level or uneven, and as either hard, carpeted with relatively even carpet, or carpeted with shaggy or uneven carpet.

Details about examiner behavior that may explain variability between examiners included the techniques used to overcome challenges to measurement.

Quality Assurance and Quality Control

Calibration of the portable Seca and Tanita scales and the portable stadiometer used in the MEC examinations showed that all pieces of equipment were within tolerance when calibrated. The four portable Seca scales and four portable stadiometers used in home examinations were all within tolerance levels when calibrated, indicating that all study measurements were taken by properly functioning equipment. The Tanita scales are self-calibrating; thus, no results are available for this calibration process. Calibrations of the four Omron devices used in home examinations showed that all devices were accurate when calibrated.

Examiner training was another integral part of quality assurance. Each examiner was observed three or more times by subject matter experts and study staff. Observers used a quality assurance checklist to document and evaluate examiners' performance. Observers did not correct an examiner during the examination. Based on these observations, two "lessons learned" teleconferences were held with examiners, supervisors, and observers.

The data collection process was monitored by reviewing response rates and component completion rates. Basic descriptive statistics were also calculated for the physical examination and biospecimen results. A weekly conference call was held with subject matter experts and study staff to discuss the data collection process, including discussion of the examinations observed by subject matter experts and any data collection issues encountered by the field staff.

Statistical Analysis

Operations metrics

Several operational metrics were collected that allowed explicit comparison of the performance of health technicians and field interviewers. The means and standard deviations of the component duration times were calculated by examiner type and month of examination. Significance of the differences found by examiner type and examination month was determined using paired t tests (double-sided, $p < 0.05$). The percentage of homes in which one or both examiners reported a home-specific operational challenge was also calculated. The use of hand-warming techniques prior to DBS collection is used as an example of overcoming operational challenges. Difficulties getting blood during the DBS collection as well as data on blood pressure cuff selection are presented separately.

Comparative analysis of height and weight

To accompany the operational results, a comparative analysis of height and weight measurements was done. These two measures were chosen to illustrate the strengths of the HMHS study design and data collected. Height and weight were expected to be stable during the 1- to 3-week period between a participant's initial NHANES MEC examination and the HMHS home examination. Future analyses will assess other measurements taken in the home relative to the standard MEC measurements.

The height and weight components were the only components to fully utilize the HMHS study design and to have four repeated measurements to assess variability due to equipment, environment, and examiner type. Mean and standard deviations were calculated for each of the four repeated measures: health technician using standard MEC equipment at the MEC; health technician using portable stadiometer, Seca scale, and Tanita scale at the MEC; health technician using portable stadiometer, Seca scale, and Tanita scale in the home; and field interviewer using portable stadiometer, Seca scale, and Tanita scale in the home.

Within-participant differences in height and weight between repeated measurements were calculated. Variability between equipment types was addressed by comparing the values obtained at the MEC using portable equipment to the values obtained at the MEC using standard equipment, keeping environment and examiner type constant. Variability between portable scales was addressed by comparing the value obtained by the Tanita scale to the value obtained by the Seca scale, keeping examiner type and environment constant. Variability between environments was addressed by comparing the values obtained by the health technician in the nonstandardized home environment to the values obtained by the health technician in the standardized MEC environment, keeping equipment and examiner type constant. Variability in examiner type was addressed by comparing the measurements obtained at the home by the field interviewer to the measurements obtained at the home by the health technician, keeping environment and equipment constant. An "overall" difference was calculated by comparing the values obtained by field interviewers in the home using portable equipment to the values obtained by the health technicians at the MEC using standard MEC equipment.

Paired t tests (double-sided, $p < 0.05$) were used to determine statistically significant differences in measurement values. To summarize the range of differences between measurements, the proportion of values that were within 2 cm (for height) and 2 kg (for weight) were calculated. Correlations for each pair of measurements were assessed with Pearson's correlation coefficients.

The number of height corrections (separate measurements of buns, braids, or other objects on top of the head that could interfere with measurement of height) was assessed for each set of measurements.

In addition, height and weight were used to compute body mass index (BMI) using the formula BMI equals weight in kilograms divided by height in meters squared (kg/m^2). BMI was used to classify individuals as obese (BMI of 30 or more) or nonobese (BMI less than 30) within each of the measurement types (defined by examiner type, scale type, and location). Sensitivity and specificity of the different measurement types were calculated relative to the NHANES MEC "goldstandard" (health technician using standard MEC equipment and protocols at the MEC).

Sensitivity is the proportion of truly obese classified as obese by the measurement type. Specificity is the proportion of the truly nonobese classified as nonobese by measurement type.

All analyses were unweighted and did not account for the complex sample design of the NHANES. HMHS is a pilot study and is not intended to be representative of the adult population in the United States. Statistical analyses were performed using the software products SAS 9.2 for Windows (Cary, N.C.) and STATA 11.1 (College Station, Texas).

Results

Sample Description

Demographic characteristics of the sample are shown in Table 1. One hundred thirty-three NHANES participants were successfully recruited to participate in HMHS, with three broken appointments for a total of 130 participants with completed examinations. Of the 130 participants, 54.6% were male. Slightly less than one-half of the sample (45.4%) was aged 18–39, while the remainder was split among those aged 40–59 (24.6%) and 60 and over (30.0%). Most participants were non-Hispanic white (51.5%), 33% were non-Hispanic black, and the rest were Hispanic or other races. The randomization of the examiner order was successful: Field interviewers performed the first set of examinations 52% of the time, and health technicians performed the first set of examinations 48% of the time. On average, home examinations occurred approximately 1 week after the participant's NHANES MEC examination (mean: 8.5 days, standard deviation: 5.5, range: 1–24 days).

Operations Metrics

Survey equipment data and Home Exam Debriefing Questionnaire data were used to assess operational metrics in the home examinations. Examiner type differences in component durations,

completion rates, and examination techniques are reported in this section. Next, the percentage of home examinations with various environmental characteristics and participant behaviors during the home examination are reported. Lastly, equipment metrics, including accuracy of blood pressure cuff assignment, are discussed.

Home examination component durations (in minutes) by examiner type were compared (Table 2). For the study overall, the mean durations for anthropometry (height and weight measurements only) did not differ by examiner type (2.7 minutes for field interviewer and 2.8 minutes for health technician). The other two components took substantially more time and also differed by examiner type (DBS: 15.3 minutes for field interviewer, 12.5 minutes for health technician; blood pressure: 17.5 minutes for field interviewer, 13.7 minutes for health technician). There were differences in blood pressure protocols by examiner type: Field interviewers took a second set of measurements over a participant's sleeve. When the analysis is restricted to the 38 participants wearing sleeveless shirts (who would, therefore, not have a second "sleeved" measurement), the mean durations were no longer significantly different (13.2 minutes for field interviewer and 13.7 minutes for health technician).

Changes in mean component durations over time were compared by examiner type (Figure 2). Health technicians had significant reductions in component length between the start and end of the study in all components; field interviewers had significant reductions in component length in blood pressure and DBS, but not anthropometry.

Component completion rates were also compared by examiner type. Both the field interviewers and the health technicians obtained weight measurements with the Tanita scale and height measurements from 100% of the participants (Table 2). The technicians also obtained weight measurements using the Seca scale from 100% of participants, while the field interviewers obtained weight measurements using the Seca scale from all but one of the

participants (99.2%). A similarly high level of successful blood pressure and DBS data collection was observed. All but two of the field interviewer examinations (98.5%) and all but one of the health technician examinations (99.2%) included three systolic and diastolic blood pressure measurements. Of the 125 DBS cards obtained by field interviewers, 96.8% had four or five blood spots. Of the 125 DBS cards obtained by health technicians, 96.0% had four or five blood spots. It was possible to obtain the complete set of analytes from nearly all of the cards, including those with fewer than five spots. All but one of the interviewer cards (99.2%) and all but two of the technician cards (98.4%) yielded complete analyte values. One of the health technician's cards did not have sufficient quantity for analysis, while the other two incomplete cards yielded HbA1c and HDL but not total cholesterol. None of these differences in completion rate by examiner type were significant.

Experience with the health sciences may influence not only component duration and completion but also examiner technique, which may in turn cause variability. For example, health technicians were more likely to use hand-warming techniques before beginning DBS collection (83.2% of examinations), while field interviewers used them in only 30.4% of examinations. However, this did not always translate into significant differences in data collection; health technicians were about as likely to prick only one finger to obtain complete DBS cards as were field interviewers (87.2% of examinations compared with 80.0% of examinations, not significant at $p = 0.07$).

The Home Exam Debriefing Questionnaires provided information on variability between the home environment and the standard MEC environment. In more than 70% of homes, one or both examiners reported some environmental issue that could have introduced variability in measurements (Table 3). Although the MEC visit schedule is engineered to minimize disruption during an examination component, 65.4% of home
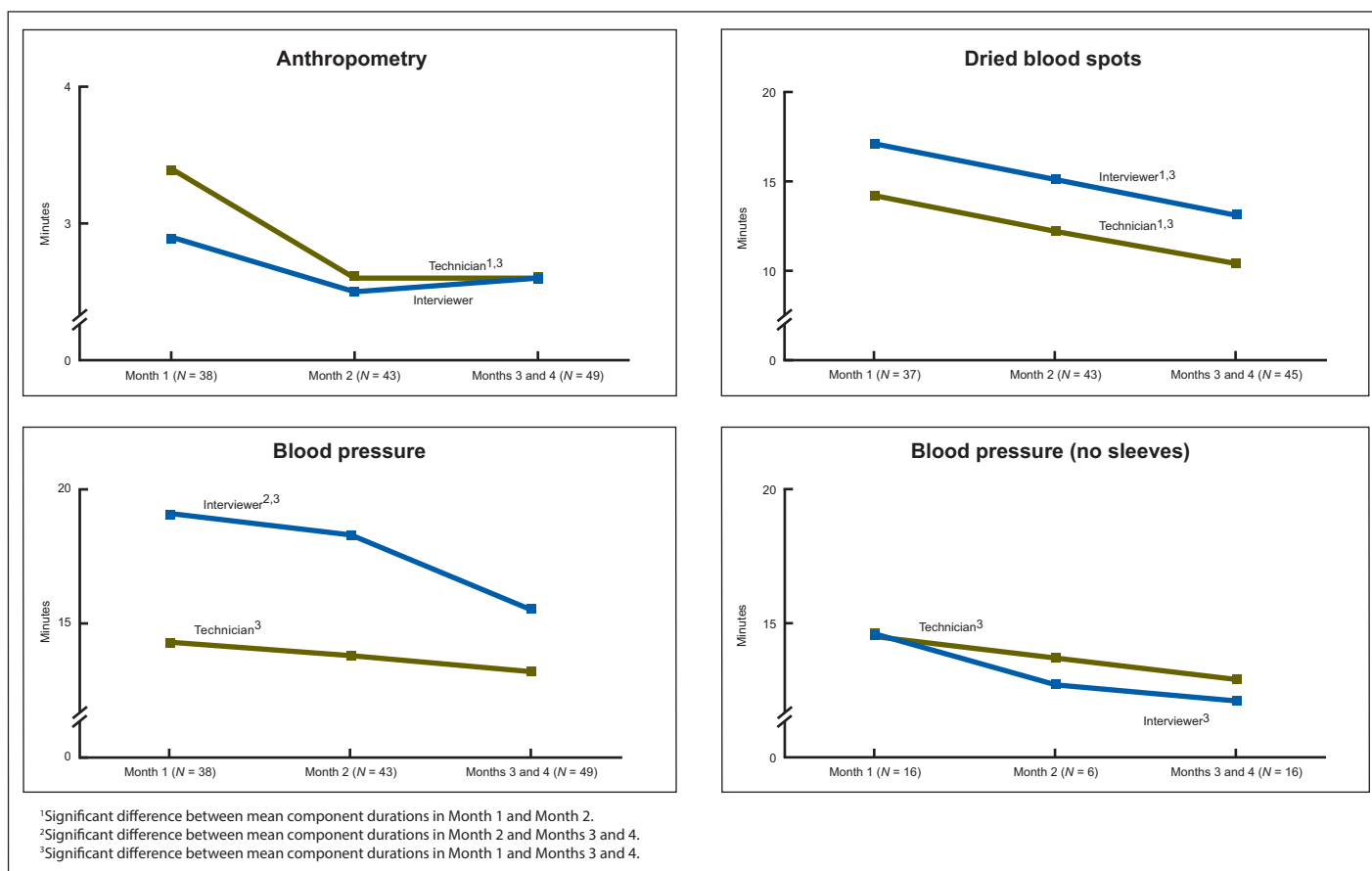
Figure 2. Mean duration of each component, by examiner type and month of study

[1]Significant difference between mean component durations in Month 1 and Month 2.
[2]Significant difference between mean component durations in Month 2 and Months 3 and 4.
[3]Significant difference between mean component durations in Month 1 and Months 3 and 4.

examinations had some sort of noise, distraction, or disruption during the examination. In 34.6% of participants' homes, one or both examiners reported a participant-initiated or environmental disruption of the blood pressure measurement. In 4.6% of participants' homes, no appropriate table or chair was available. In 6.2% of the homes, the temperature seemed either hot or cold, with most examiners indicating ''hot.'' In 15.4% of participants' homes, the floor was either not level or carpeted, which was suboptimal for weight and height measurements.

In one home with a low ceiling, the examiner had to set up the stadiometer outside. One home did not have a table or a chair, so furniture was improvised with a step stool, a stack of clothes and blankets, and a tray table. Housemates, children, and pets all contributed to the nonstandardized environment of the home examination. No disruptive or suboptimal conditions occurred in only 37 of the 130 homes (28.5%).

Portable equipment may also be a source of measurement variability. In addition to representing an extra burden on examiners, the process of transporting bulky or heavy equipment over treacherous terrain or even just in and out of homes can place the equipment at risk of breakage or loss of precision. In more than one-fifth of cases, examiners reported difficulty transporting the suitcase (Table 3). The two most common difficulties were carrying the equipment up stairs and rolling it through gravel or debris on a driveway. In some cases, field interviewers reported injuries from carrying the equipment in the suitcase. In addition to stairs, they reported encountering steep hills, broken and crowded steps, and unstable decks.

After the equipment was in the home, it generally worked well. In only three homes (2.3%) did one or both examiners report a problem with the equipment. There were four reports of problems with the Omron machine, two by technicians and two by field

interviewers (in one home, both examiners had problems). Examination of the Omron error codes indicated that these errors may have been due to either participant movement during the measurement, participant arrhythmia, examiner error, or insufficient inflation of the blood pressure cuff. No equipment problems were reported for the scales or the DBS equipment.

Blood pressure cuff size selection was another source of equipment variation in this study. For the NHANES MEC examination, blood pressure cuff size was selected by directly measuring the midarm circumference of the participant. In contrast, the home examination protocol used a regression equation to select the cuff size. The regression equation used the participant's age, sex, and height and weight (measured in the home). In all 130 examinations, the regression equation selected the same size cuff for the field interviewer and the health technician. The home protocol using the regression equation correctly cuffed

86% of participants compared to cuff sizes that would have been selected based on the MEC measurements (Table 4). Of the participants with discrepant cuff sizes, most (82%) were given larger cuff sizes based on the regression equation.

Reports also were made of participant discomfort, which could represent extra burden on both the participants and examiners (who need to be able to respond appropriately to such issues). For example, two participants were lightheaded or nauseated during the DBS collection, and one participant kept bleeding after the DBS were completed. In addition, the blood pressure and DBS caused distress in some participants. Six participants who had consented to DBS collection indicated that they were uncomfortable during the procedure; one participant was uncomfortable with DBS and refused the collection. Similarly, four participants indicated that they were uncomfortable either during the blood pressure measurement or during the waiting periods that accompanied the measurement.

Comparative Analysis of Height, Weight, and BMI

Height

The mean height of the full sample obtained at the MEC by a trained health technician using the standard MEC equipment was 168.8 cm (Table 5). Measurements taken in the same setting by an examiner of the same skill level but using portable equipment yielded shorter heights in the paired sample analysis; the mean height obtained at the MEC by a health technician using the portable Seca stadiometer was 168.5 cm. The mean height obtained in the home by the health technician using portable equipment was 168.8 cm, which was taller than the measurement at the MEC by an examiner of the same skill level using the same equipment in the paired sample analysis. No significant differences were observed between the height measurements obtained by health technicians and field examiners. There was no significant difference between

the height measurement obtained at the MEC by the health technician with standard MEC equipment and the height obtained in the home by the field interviewer with the portable equipment in the paired sample analyses (Table 6). Pearson's correlation coefficients for all comparisons were above 0.99 ($p < 0.0001$).

Almost all paired differences in all four height measurement comparisons fell within the specified ± 2 cm range (environments, comparing health technician in the MEC with health technician in the home: 97% within ± 2 cm; examiners, comparing health technician in the home with field interviewer in the home: 100% within ± 2 cm; equipment, comparing standard MEC equipment at MEC with portable equipment at MEC: 97% within ± 2 cm; overall, comparing MEC health technician with standard equipment with home field interview with portable equipment: 96% within ± 2 cm).

During the MEC visits, four "above the waist height corrections" were made: three by the health technician using standard MEC equipment, and one by the health technician using the portable equipment. This type of height correction is used if a participant has hair ornaments, jewelry, buns, or braids that interfere with the stadiometer headpiece placement (24). Three of the height correction values (the height of the objects) at the MEC were 2 cm or less. All of these height corrections were made to different participants even though two measurements were taken per participant at the MEC. During the home visits, seven height corrections were made: One was made by the health technician, and six by the field interviewer. Five of the height correction values in the home were 2 cm or less. Two of these height corrections were made to the same participants. Most cases that had at least one height correction had an additional source of variability, because any uncorrected height values may not have completely accounted for the height of hairstyles.

Weight

While height would not be expected to vary during the period between the

MEC and home examinations, weight could. However, the analysis was approached with the assumption that the expected difference between weight measured at the MEC and weight measured at home should be zero. The mean weight obtained at the MEC by a health technician using the standard MEC equipment was 80.5 kg (Table 5). The mean weight obtained at the MEC by a health technician using the portable Seca scale was 80.4 kg, which did not differ significantly from the measure obtained using standard MEC equipment in the paired sample analysis (Table 6). The mean weight obtained in the home by the health technician using the Seca scale was 81.0 kg, which was heavier than the value obtained using the same equipment in the MEC in the paired sample analysis. No significant differences were observed in the weight measurements obtained between examiners in the paired sample analysis. The weight obtained in the home by the field interviewer using the Seca scale was 0.6 kg heavier than the weight measurement obtained at the MEC by the health technician using standard MEC equipment in the paired sample analysis. Pearson's correlation coefficients for all comparisons were above 0.99 ($p < 0.0001$). Almost all paired differences between examiners and between equipment fell within the specified ± 2 kg range (examiner: 100% within ± 2 kg; equipment: 99% within ± 2 kg). Environment and overall comparisons found more pairs with larger differences (environment: 88% within ± 2 cm; overall: 89% within ± 2 kg).

The mean weight obtained at the MEC by a health technician using the portable Tanita scale was 80.8 kg, which was heavier than the measurement obtained using standard MEC equipment (80.5 kg) in the paired sample analysis. The mean weight obtained in the home by the health technician using the Tanita scale was 81.1 kg, which was heavier compared with the value obtained at the MEC using the same equipment in the paired sample analysis. There was no difference between the weight measurements obtained by each examiner in the paired sample analysis. The weight obtained by the field

interviewer using the Tanita scale in the home was 0.7 kg heavier than the standard MEC weight measurement in the paired sample analysis. Pearson's correlation coefficients for all comparisons were above 0.99 ($p < 0.0001$). Almost all paired differences between examiners and between equipment fell within the specified ± 2 kg range (examiners, comparing health technician in the home with field interviewer in the home: 100% within ± 2 kg; equipment, comparing standard MEC equipment at MEC with portable equipment at MEC: 98% within ± 2 kg). Environment and overall comparisons found more pairs with larger differences (environments, comparing health technician in the MEC with health technician in the home: 90% within ± 2 cm; overall, comparing MEC health technician using standard equipment with home field interviewer using portable equipment: 88% within ± 2 kg).

At the NHANES MEC, the mean Tanita scale values were approximately 0.4 kg heavier than the Seca scale values in the paired comparisons (Table 7). In participants' homes, the mean Tanita scale values were approximately 0.1 kg heavier than the Seca scale values in the paired comparison. This was consistent across examiner types.

BMI

Participants were classified as obese (BMI of 30 or more) or nonobese (BMI less than 30) using standard MEC measurements and by each of the other measurement types (defined by location, examiner type, and scale type). The standard MEC measurements were considered to be the gold standard, and classified 42 participants (32.3%) as obese. The sensitivity of all of the measurement types was 100% relative to the gold standard, indicating that each measurement type was able to correctly identify obese individuals (Table 8). The specificity of each of the four measurements obtained by the health technicians was 97% or greater relative to the gold standard. The specificity of the two measurements obtained by the field interviewers was 100% relative to the gold standard, indicating perfect or

near-perfect ability to correctly identify nonobese individuals who had been classified as nonobese by standard MEC measurements.

Discussion

Summary

HMHS was designed to identify and assess sources of variability that could make in-home collection differ systematically from standardized collection in the NHANES MEC. The operational findings helped to highlight areas that may be sources of variability in future in-home collection of physical measures. Comparative height and weight measurements helped to quantify differences attributable to using portable equipment, conducting measurements in a nonstandardized home environment, and having field interviewers collect physical measurements.

Operational findings from HMHS highlighted areas with potential for variability. One potential source of variability between measurements taken by the standard MEC equipment and portable equipment was that frequently moving the portable equipment could place the equipment at risk of breakage or loss of precision. Few problems occurred with equipment performance within the home, and all calibration results indicated that the portable equipment functioned properly. However, examiners reported difficulty in transporting equipment in and out of the home, which could lead to broken or less precise equipment in a longer study period. Differences in the home and MEC environments were another potential source of variability between measurements. Many of the home environments encountered would be considered suboptimal for data collection when compared with the NHANES MEC. Findings indicated that noise and distractions, which could particularly affect blood pressure measurement, were common in the home. The gap between health technicians' and field interviewers' health sciences training could be another source of variability. However, while differences were noted between

examiners in the duration of the DBS component, even this disappeared over the course of 3 months.

Comparative results of height and weight indicate some slight differences with respect to equipment, environment, and examiner skill level. Within the MEC, the portable stadiometer underestimates height and the Tanita scale overestimates weight relative to the standard MEC equipment. When using the same portable equipment, measurements at home overestimate both height and weight relative to the MEC environment. For weight, this could be due to the clothing that participants wore in their homes (rather than the disposable gown used in the MEC), differences in what they ate before each examination, or real changes in weight during the time period between MEC and home examinations. For height, this can be due to the height corrections for hairstyles that participants wore in their homes. While only seven participants had height corrections, none had a height correction on all four sets of height measurements, and only two participants had height corrections from both examiners on a given day, indicating that this part of the height measurement protocol may have introduced another source of variability. No differences in height or weight values between examiners were found. While the above-mentioned differences were statistically significant, there seemed to be little practical significance. Each of the measurements in the home was able to perfectly or near-perfectly classify obesity relative to the NHANES MEC gold standard measurement.

Taken together, these findings are particularly useful. Distractions, disruptions, or suboptimal physical conditions were present in many homes, and yet the examiners were successful in obtaining nearly all measurements and were able to obtain accurate height and weight measurements.

Previous work comparing in-home measures with NHANES estimates for a similar population has suggested that discrepancies could be due to differences in population composition as well as differences in equipment and protocols (21). The HMHS design

addressed differences in the sample population by taking repeated measurements of the same participants. The HMHS design sought to keep protocols as similar as possible to those used in the MEC to better evaluate the effects of the portable equipment as well as the nonstandardized environment.

Lack of appropriate furniture in the home, interruptions, and demands on the participants by children and animals were all unanticipated environmental challenges that occurred in this study. To reduce their impact on accuracy in future data collection efforts, these issues must be anticipated and incorporated into protocol development, data collection, and interviewer training.

Recent work on in-home physical measurement and biospecimen collection from the United Kingdom examined the feasibility of collection by interviewers rather than nurses (22). The operational findings in this report were largely consistent with this study. The HMHS design has the added value of the standardized examinations in the MEC, providing additional comparative physical measurement and biospecimen information for the same participant.

The current analysis did not compare the impact of equipment and protocols on blood pressure measurements or blood analytes. However, in an examination of equipment-related operational issues, participants who were incorrectly cuffed were more likely to receive a larger cuff than they would have received if the midarm circumference had been measured directly. In an examination of participant discomfort, several participants expressed discomfort with the DBS collection. This is significant, given that this survey consisted entirely of compensated volunteers who had already completed the NHANES examination. Appropriate responses to distress as well as physical problems, such as lightheadedness, nausea, or continued bleeding following DBS collection must be planned for before these measures can be considered for a large population survey such as NHIS.

Limitations

The internal validity of the HMHS was subject to several limitations. For the analysis of operations metrics, the performance of field interviewers was compared with the performance of health technicians in the home with respect to component duration, component completion, and techniques. While this analysis assumes that the environmental challenges (e.g., lack of appropriate furniture or uneven flooring) were present in both examinations, some challenges (e.g., distractions or noise) may have only been present in one examination. The Home Exam Debriefing Questionnaire was an attempt to quantify how often this occurred.

Due to software limitations, component times rather than item times were collected, making it more difficult to detect differences in blood pressure component durations between health technicians and field interviewers. The analysis restricted just to those participants wearing sleeveless shirts was an attempt to address this limitation.

This study also assumed that physical separation of the two examiners in the home would be sufficient to render their measurements independent of one another. However, participants may have consciously or unconsciously tried to "help" the second examiner by preparing themselves for the second set of measurements (e.g., fist pumping for DBS or correct positioning for height, weight, and blood pressure). This may have resulted in an underestimate of the difference between examiners. Further research should more closely examine any effects of examiner order on measurement differences.

The current design was powered to detect two standard deviation differences in repeated height and weight measures. The sample size may not be sufficient to detect differences when stratified by other factors of interest, such as sex or race and ethnicity.

Finally, participants in the HMHS were selected from NHANES participants who had already completed some portion of the MEC examination

and received remuneration. This results in a group of participants that has demonstrated a willingness to participate in research and may be more compliant than other participants.

Directions for Future Research

Future work should address some of the issues that were out-of-scope for this study or could not be studied in this timeframe. This includes developing the optimal type and amount of training for field interviewers, not only on obtaining physical measures and biospecimens, but also on universal precautions for bloodborne pathogens and dealing with participant medical emergencies. Further research is needed on the impact that adding physical measurements and biospecimen collection would have on response rates for a household interview survey like NHIS, where the interview portion alone can reach about 1 hour. A study with a longer survey period that went into more types of homes could also answer questions about longevity of the portable equipment as well as its practicality in a range of home environments. With the information gained about the range of environments from this study, future data collection tools could capture more information about the type and timing of distractions, as well as pertinent details about the physical environment challenges encountered.

While this report contained a statistical comparison of height and weight, assessments of other components are forthcoming.

Conclusions

HMHS demonstrates that physical measurements and biospecimen data can be collected by field interviewers in a home environment using portable equipment. Height and weight measurements taken in the home were fairly accurate when compared with the measures taken about 1 week earlier in the NHANES MEC. HMHS had a long training period for a few well-supervised interviewers and an optimal participant

recruitment situation. Adding physical measurements and biospecimen collection to a large household interview survey such as NHIS requires additional study on the possible impact on response rates and the need for appropriate incentives. Home environments can be challenging places to collect physical measures and biospecimens. The implications of these operational challenges need to be explored.

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Table 1. Health Measures at Home Study demographic characteristics, 2012

Characteristic	Number of participants (percent)
Total	130 (100%)
Sex:	
Male	71 (54.6%)
Female	59 (45.4%)
Age group:	
18–39	59 (45.4%)
40–59	32 (24.6%)
60 and over	39 (30.0%)
Race/ethnicity:	
Non-Hispanic white	67 (51.5%)
Non-Hispanic black	43 (33.1%)
Hispanic and/or other races	20 (15.4%)

Table 2. Operations metrics during a home exam, by examiner type: Health Measures at Home Study, 2012

	Examiner	
Operational characteristic	Field interviewer	Health technician
Duration (minutes)	Mean (standard deviation)	
Height and weight	2.7 (1.6)	2.8 (1.3)
Dried blood spots	15.3 (6.4)	[†]12.5 (3.7)
Blood pressure[1]	17.5 (5.1)	[†]13.7 (2.2)
Blood pressure (among participants wearing sleeveless shirts, so the protocol did not differ by examiner type)	13.2 (2.7)	13.7 (2.1)
Completion	Participants N (percent)	
Height measurements	130 (100.0)	130 (100.0)
Weight measurements with Seca sale	129 (99.2)	130 (100.0)
Weight measurements with Tanita scale	130 (100.0)	130 (100.0)
Three systolic and diastolic blood pressure measurements	128 (98.5)	129 (99.2)
Four or five blood spots, reported[2]	121 (96.8)	120 (96.0)
Complete analytes from blood spots[2]	124 (99.2)	123 (98.4)
Technique	Participants N (percent)	
Use of hand-warming techniques, not including fist pumping	38 (30.4)	[†]104 (83.2)
Pricked two fingers	25 (20.0)	16 (12.8)
Five blood spots from one finger	99 (79.2)	108 (86.4)

† $p < 0.001$.

[1]In cases where the participant was wearing clothing with sleeves, the interviewer's complete blood pressure component duration includes the time needed for a second set of measurements over the sleeve, while the health technician's blood pressure component duration does not.

[2]Dried blood spots were collected from only 125 participants due to contract limitation.

Table 3. Environmental and equipment issues in home during one or both home exams: Health Measures at Home Study, 2012

Issue	N (percent)
Any environmental issue	93 (71.5%)
Social environment	
Any type of noise, distraction, or disruption during either home exam[1]	85 (65.4%)
Background noise (e.g., televisions, sirens, or lawnmowers)	60 (46.2%)
Other people talking or making noise	59 (45.4%)
Telephone calls	18 (13.9%)
Participant or environmental disruption of blood pressure measurement (includes noise)	45 (34.6%)
Structural environment	
No appropriate table or chair	6 (4.6%)
Extreme temperatures in the home	8 (6.2%)
Suboptimal floor	20 (15.4%)
Equipment	
Difficulty transporting suitcase	28 (21.5%)
Any equipment problem (including equipment failures)	3 (2.3%)

[1]Includes background noise, other people, telephone calls, and disruption of blood pressure measurement. These sum to more than 100 percent as multiple types of noise and distractions could have occurred during each exam.

NOTE: Data were collected in the homes of 130 participants.

Table 4. Blood pressure cuff size assigned at home, by size needed: Health Measures at Home Study, 2012

Omron cuff size assigned by the regression equation[1]	Cuff size (determined by direct arm circumference measurement in MEC)		
	Adult (N = 64)	Large adult (N = 62)	Extra-large adult (N = 4)
Adult	52 (81.3%)	3 (4.8%)	0 (0%)
Large adult	12 (18.7%)	57 (91.9%)	0 (0%)
Extra-large adult	0 (0%)	2 (3.2%)	4 (100%)
Total	64 (100%)	62 (100%)	4 (100%)

[1]Agreement between cuff size needed and cuff size assigned at home is reported for 130 participants, including the two participants for whom the blood pressure measurement was incomplete.

NOTE: MEC is mobile examination center.

Table 5. Mean height and weight measurements: Health Measures at Home Study, 2012

Examiner equipment	MEC		Home	
	Health technician, standard MEC	Health technician, portable equipment	Health technician, portable equipment	Field Interviewer, portable equipment
Height				
Fixed stadiometer	168.8 cm	. . .	. . .	. . .
Seca stadiometer	. . .	168.5 cm	168.8 cm	168.8 cm
Weight				
Fixed scale	80.5 kg	. . .	. . .	. . .
Seca scale	. . .	80.4 kg	81.0 kg	81.0 kg
Tanita scale	. . .	80.8 kg	81.1 kg	81.1 kg

. . . Category not applicable.

NOTE: MEC is mobile examination center.

Table 6. Mean between-measurement (paired sample) differences for height and weight: Health Measures at Home Study, 2012

	Height	Weight	
Comparison	Seca stadiometer	Seca scale	Tanita scale
	Mean (standard deviation)		
Environment: MEC HT with portable equipment, home HT with portable equipment	[†]−0.2 (0.80)	[‡]−0.6 (1.21)	[†]−0.3 (1.20)
Examiner: Home HT with portable equipment, home FI with portable equipment	0.0 (0.44)	−0.0 (0.16)	−0.0 (0.17)
Equipment: MEC HT with standard MEC equipment, MEC HT with portable equipment.	[†]0.3 (0.88)	0.0 (0.59)	[†]−0.3 (0.54)
Overall: MEC HT with standard equipment, home FI with portable equipment	0.1 (0.96)	[†]−0.6 (1.20)	[†]−0.7 (1.20)

† $p < 0.01$.
‡ $p < 0.001$.

NOTES: MEC is mobile examination center, HT is health technician, and FI is field interviewer.

Table 7. Mean measurements and mean between-measurement differences between scales for weight: Health Measures at Home Study, 2012

	MEC	Home	
Examiner	Health technician	Health technician	Field interviewer
	Means		
Seca scale	80.4 kg	81.0 kg	81.0 kg
Tanita scale	80.8 kg	81.1 kg	81.1 kg
	Mean differences (standard deviation)		
Seca compared with Tanita	[†]−0.4 (0.26)	[†]−0.1 (0.08)	[†]−0.1 (0.06)

† $p < 0.001$.

NOTE: MEC is mobile examination center.

Table 8. Validity of obesity classification, by measurement type: Health Measures at Home Study, 2012

Measurement type	True positive[1]	False positive	True negative	False negative	Sensitivity (percent)	Specificity (percent)
MEC health technician, portable stadiometer, Seca scale	42	1	87	0	100	98.9
MEC health technician, portable stadiometer, Tanita scale	42	2	86	0	100	97.7
Home health technician, portable stadiometer, Seca scale	42	1	87	0	100	98.9
Home health technician, portable stadiometer, Tanita scale	42	2	86	0	100	97.7
Home field interviewer, portable stadiometer, Seca scale[2]	42	0	87	0	100	100.0
Home field interviewer, portable stadiometer, Tanita scale	42	0	88	0	100	100.0

[1]Standard MEC measurement (MEC, fixed scale, fixed stadiometer) is the gold standard for validity statistics. Statistics are based on MEC identification of 42 participants as obese (32.3%) and 88 participants as nonobese (67.7%). Obesity was defined as BMI (kg/m^2) of 30 or greater.
[2]Data for this category are based on a sample size of 129.

NOTES: MEC is mobile examination center, and BMI is body mass index.

Appendix

NHANES 2012 HMHS
Home Exam Debriefing Questionnaire

Please complete this form immediately following the exam, once you are outside the home.

*SPID*_____ *Examiner ID*_____ *Date*_____

Dried Blood Spots (DBS)

1. Did the SP refuse to participate in the DBS?

   1. □ *No → If No, go to question 3*

   2. □ Yes

2. If the SP refused to participate in the DBS, why did they refuse? (*Check all that apply*)

   1. □ SP cited a medical condition (such as bloodthinners, recent blood work, or daily diabetes glucose checks)

   2. □ SP reported unease with potential pain, fear of needles, or dislike of blood

   3. □ SP reported that they did not think that providing blood was appropriate

   4. □ SP reported that they believed the measure was too invasive or dangerous

   5. □ SP's family or household member did not think that providing blood was appropriate

   6. □ SP's family or household member believed that the measure was too invasive or dangerous

   7. □ No reason given for refusal

If the SP refused to participate in the DBS, go to question 9 (Height section)

3. What temperature were the SP's hands, initially?

   1. □ Unusually cold

   2. □ Unusually warm

   3. □ Neither unusually cold nor unusually warm

   4. □ I could not discern the temperature of the SP's hands

4. What temperature were the SP's hands during DBS collection?

   1. □ Unusually cold

   2. □ Unusually warm

   3. □ Neither unusually cold nor unusually warm

   4. □ I could not discern the temperature of the SP's hands

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Dried Blood Spots (DBS) (continued)

5. Did the SP use any hand-warming techniques? (*Note: hand shaking and pumping are intended to increase blood flow; they are not hand-warming techniques*)

1. ☐ No → *If No, go to question 7*

2. ☐ Yes

6. Which hand-warming techniques did the SP use? (*Check all that apply*)

1. ☐ Hand warmers

2. ☐ Rubbing their hands together

3. ☐ Running their hands under warm water

4. ☐ Other (*please specify*):⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

7. Did any problems occur during the collection of the DBS?

1. ☐ No → *If No, go to question 9 (Height section)*

2. ☐ Yes

8. What problems occurred during the collection of the DBS? (*Check all that apply*)

1. ☐ SP appeared agitated or distressed

2. ☐ SP became light-headed or nauseated

3. ☐ SP fainted

4. ☐ SP had difficulty getting finger to stop bleeding

5. ☐ Problems getting blood

6. ☐ No standard table and/or chair available, so used other furniture or objects during collection (*please specify*):⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

7. ☐ Problem with equipment or supplies but was still able to completely collect DBS (*please specify*):⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

8. ☐ Other problem (*please specify*):⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

Height

9. If you could not obtain the height measurement, please explain why.

1. ☐ Not applicable; I obtained the height measurement

2. ☐ SP refused

3. ☐ Other reason:⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

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Weight

10. If you could not obtain the weight measurement, please explain why.

1. □ Not applicable; I obtained the weight measurement

2. □ SP refused → *Go to question 15 (Blood Pressure section)*

3. □ Other reason:_____

11. Was the floor on which you placed the scales level?

1. □ No

2. □ Yes

12. How would you describe the floor on which you placed the scales?

1. □ Hard floor

2. □ Carpeted floor with relatively even carpet

3. □ Carpeted floor with shaggy or uneven carpet

13. Were the floor conditions the same for both scales?

1. □ No (*please explain*):_____

2. □ Yes

14. Did the SP appear embarrassed or distressed just before, during, or just after the weight measurement?

1. □ No

2. □ Yes

Blood Pressure

15. If you could not obtain the blood pressure measurement, please explain why.

1. □ Not applicable; I obtained the blood pressure measurement.

2. □ SP refused → *Go to question 24 (General section)*

3. □ Other reason:_____

16. Did you measure blood pressure <u>over a sleeve</u>?

1. □ No → *Go to question 18*

2. □ Yes

17. If you measured blood pressure over a sleeve, what was the thickness of the sleeve?

1. □ Thin (such as t-shirt or shirtsleeves)

2. □ Thick (such as knit or sweater)

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Blood Pressure (continued)

18. Did you use <u>cushions or padding</u> to raise the arm to heart level during blood pressure measurement?

    1. ☐ No

    2. ☐ Yes   How many?_____

19. If you had to restart the 5-minute waiting period, please explain why.

    1. ☐ Not applicable; I did not have to restart the waiting period

    2. ☐ Reason:_____

20. Did the SP sit quietly during the entire blood pressure measurement?

    1. ☐ No (*please explain*):_____

    2. ☐ Yes

21. Did the SP appear uncomfortable during the blood pressure measurement or complain that the blood pressure cuff was too tight?

    1. ☐ No

    2. ☐ Yes

22. Did any problems occur during the blood pressure section?

    1. ☐ No → *If No, go to question 24 (General section)*

    2. ☐ Yes

23. What problems occurred during the blood pressure section? (*Check all that apply*)

    1. ☐ Noisy or chaotic environment

    2. ☐ SP willing but unable to roll up sleeve

    3. ☐ Unable to pull sleeve entirely out of the way so it bunched at the top

    4. ☐ Omron machine placed on the floor because no higher surface available

    5. ☐ No chair with back available, so SP sat somewhere else (*please specify*):

       _____

    6. ☐ Problem with equipment but was still able to completely measure blood pressure (*please specify*):_____

    7. ☐ Other problem (*please specify*):_____

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General

24. How would you rate the quality of information obtained from this home exam?

   1. ☐ Excellent — No problems at all → *Go to question 26*

   2. ☐ Good — a few problems but overall quality is good

   3. ☐ Fair — a number of problems but overall acceptable

   4. ☐ Poor — many problems, overall quality open to question

25. If the quality of this home exam was less than excellent, what were the reasons? (*Check all that apply*)

   1. ☐ A condition that I indicated in one of the previous questions

   2. ☐ Some other reason (*please specify*)_____

   _____

26. Overall, was the atmosphere during the exam...

   1. ☐ Chaotic and noisy, therefore disruptive to the exam

   2. ☐ Some noise or interruptions, but the exam went reasonably smoothly

   3. ☐ Quiet and calm, ideal for the exam

27. Were other persons (besides staff observers) present during the exam?

   1. ☐ No

   2. ☐ Yes

28. What types of distractions or interruptions were present during the exam? (*Check all that apply*)

   1. ☐ No distractions or interruptions present

   2. ☐ Television on but SP not watching

   3. ☐ Television on and SP watching at least some of the time

   4. ☐ SP or others using telephone or cellphone (e.g., phone calls, text messages)

   5. ☐ Children present making noise or needing attention

   6. ☐ Adults present making noise or needing attention

   7. ☐ Pets or animals present making noise or needing attention

   8. ☐ Other background noise (e.g., music, cars, lawn mowers)

   9. ☐ Other (*please specify*):_____

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General (continued)

29. In your opinion, was the temperature in the exam room in the home...

    1. □ Hot

    2. □ Warm

    3. □ Cool

    4. □ Cold

30. Were you completely blinded (did not hear or see) when the other examiner performed the exam?

    1. □ No, I was not completely blinded; I heard and/or saw the other examiner perform the exam (*please explain*):_____

    2. □ Yes, I was completely blinded; I neither heard nor saw the other examiner perform the exam

31. Did you have any trouble transferring the suitcase between the car and the home?

    1. □ No

    2. □ Yes (*please explain*):_____

32. Did the SP initially resist any of the exam components?

    1. □ No → *Go to question 34*

    2. □ Yes

33. Which of the exam components did the SP initially resist? (*Check all that apply*)

    1. □ Dried blood spots

    3. □ Height

    4. □ Weight

    5. □ Blood pressure

34. Did the SP make any notable comments about the exam?

    1. □ No

    2. □ Yes (*please specify*)_____

_____

_____

Thank you for completing this form!

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